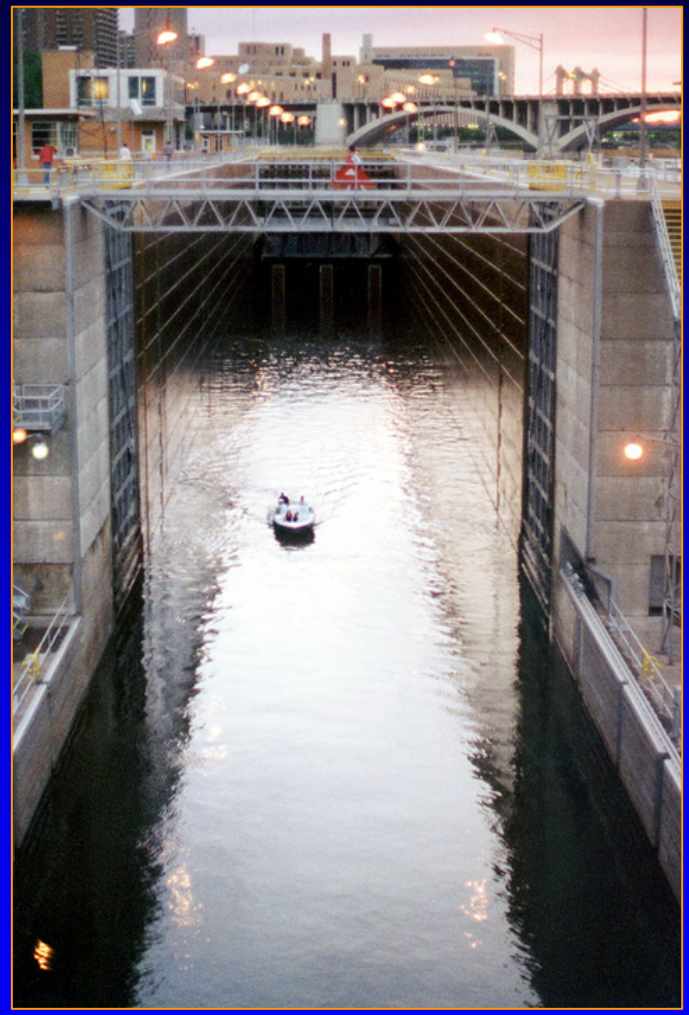
Condition Indices for Civil Works



Civil Works asset management for aging infrastructure

Tuesday August 15, 2006

Stuart Foltz and David McKay
CERL / Facilities Division

Condition Indices for Civil Works

My objectives

- Convince you that condition indexes are a necessary part of Asset Management
- Convince you that CIs will solve all problems
- Convince you to go home and use CIs

Condition Indices for Civil Works

My objectives

- ✗ Convince you that we have to use condition indexes
- ✗ Convince you that CIs will solve all problems
- ✗ Convince you to go home and use CIs
- ✓ **Appreciate what information is needed for Asset Management (macro level understanding)**
- ✓ **See condition Indexes as a family of capabilities**
- ✓ **Appreciate *condition assessment* as an Asset Management tool**

Condition Indices for Civil Works

- **This presentation:**
  - Corps CW infrastructure
  - Asset Management policy issues
  - An Asset Management viewpoint
  - CI basics
  - Simplification
    - minutiae example: miter gate anchorage assembly
    - multi-level inspection
  - Relative risk CIs
  - Conclusions
  - Questions

Condition Indices for Civil Works

Civil Works Infrastructure

- 25,000 miles navigable waterways
  - 237 lock chambers at 192 sites
  - 926 shallow and deep draft harbors
- Premier Federal flood damage reduction agency
  - 383 major reservoirs
  - 8,500 miles of levees
- Fourth largest electrical utility in U.S.
  - produces 25% of all hydropower
- Leading provider of water based recreation
- Environmental steward of 12,000,000 acres of public lands and water

Condition Indices for Civil Works

Problems Corps-Wide

- Actual Operations & Maintenance (O&M) needs far outdistance the available dollars
  - more than 50% of locks & dams reached their design life in 2000
  - rapidly growing maintenance backlog
    - maintenance, repair, rehabilitation, enhancement
  - therefore all levels of service must be justified
- No reliable (universal and consistent) or objective means of communicating O&M needs, or of quantifying the impact of budget shortfalls exists
  - both the budget development and allocation processes are largely subjective
  - target based budget allocations (historic trend)
  - annually between 16,000 to 19,000 O&M work packages are uploaded to HQUSACE

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Condition Indices for Civil Works

Executive Order 13327, "Federal Real Property Asset Management" (February 4, 2004)
http://www.whitehouse. gov/news/releases/2004/02/20040204-1.html

- Directs all major agencies to develop asset management plans.
- Creates FRPC (Federal Real Property Council) to establish guidance, and best practices.
- FRPC has identified and defined 23 mandatory Property Inventory Data Elements and Performance Measures that will be captured and reported by all agencies.

Condition Indices for Civil Works

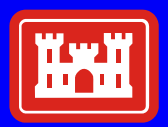
- 1. Real Property Type
- 2. Real Property Use
- 3. Legal Interest
- 4. Status
- 5. Historical Status
- 6. Reporting Agency
- 7. Using Organization
- 8. Size
- 9. Utilization (Performance Measure #1)
- 10. Value
- 11. Condition Index (Performance Measure #2)
- 12. Mission Dependency (Performance Measure #3)
- 13. Annual Operating and Maintenance Costs (Performance Measure #4)
- 14. Main Location
- 15. Real Property Unique Identifier
- 16. City
- 17. State
- 18. Country
- 19. County
- 20. Congressional District
- 21. ZIP Code
- 22. Installation and Sub-Installation Identifier
- 23. Restrictions

Condition Indices for Civil Works

- FRPC Condition Index
  - Metric

$$CI = \frac{\text{(repair cost)}}{\text{(asset value)}}$$

  - Assessment
    - Quick and dirty estimate
    - Network level accuracy
    - Project or component level accuracy



Condition Indices for Civil Works

Program Assessment Rating Tool (PART)

- Worksheet for assessing government programs
- Focused on performance measures
- Does not directly require Asset Management but such a plan will help achieve a high score

Condition Indices for Civil Works

Corps programs evaluated in PART:

(1) Coastal Ports and Harbors (Moderately Effective)
(2) Coastal Storm Damage Reduction (Results Not Demonstrated)
(3) Corps Hydropower (Adequate)
(4) Emergency Management (Moderately Effective)
(5) Flood Damage Reduction (Results Not Demonstrated)
(6) Inland Waterways Navigation (Results Not Demonstrated)
(7) Non-regulatory Wetlands Activities (Results Not Demonstrated)
(8) Recreation Management (Moderately Effective)
(9) USACE Regulatory Program (Moderately Effective)

Condition Indices for Civil Works

WRDA revision

- **WRDA 2005 limits the Corps ability to re-program project money**
- **According to Gen Riley, Dir of CW:**

  "the goal of FY 2006 program execution would be to 'accurately schedule work' based on appropriations and carry-over funds and 'then to execute the schedule.'"

  - **The Corps will need to develop more accurate and omniscient spending plans.**

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Condition Indices for Civil Works

Asset Management decision criteria

- Infrastructure condition
- Infrastructure performance
- Risk
- Economics
- Policies, Corps priorities, national priorities

Condition Indices for Civil Works

Asset Management criteria

- Infrastructure condition (family of capabilities)
  - Reliability
    - Failure probability
    - Probability of unsatisfactory performance
  - Serviceability
  - Expected remaining life

  - Repair needs
  - Age
  - Function
  - Risk (includes consequences)

Condition Indices for Civil Works

Asset Management criteria

- **Infrastructure condition**
  - Type of asset and inspection method
    - Light bulb
    - Motors
    - Roofing
    - Pavements
    - Mechanical equipment
    - Bridge
    - Miter gate
    - Levees
    - Spillways and dams

Condition Indices for Civil Works

Asset Management criteria

- Infrastructure condition
  - Business line
    - Navigation
    - Hydropower
    - Flood damage reduction
    - Recreation
    - Environment

Condition Indices for Civil Works

Asset Management criteria

- Intended use
  - Inspection
    - standard process
    - identify safety & reliability problems
  - Condition tracking
  - Budgeting (macro)
  - Prioritization
  - Work planning (micro)
  - Forecasting
    - Expected remaining life
  -
  -

Condition Indices for Civil Works

Asset Management criteria

- **metrics**
  - **(1) measurement**

NBI Rating	Description
9	Excellent Condition
8	Very Good Condition
7	Good Condition
6	Satisfactory Condition
5	Fair Condition
4	Poor Condition
3	Serious Condition
2	Critical Condition
1	Imminent Failure
0	Failed

(2)

CS	Description	
1	No evidence of active corrosion	
2	Slight peeling of the paint, pitting or surfa	
3	Peeling of the paint, pitting, surface rust	
4	Flaking, minor section loss (<10%)	
4	Flaking, swelling, moderate section loss (<30%). Structural analysis not warranted	
5	Flaking, swelling, moderate section loss (>10% but <30%). Structural analysis warranted	R3
5	Heavy section loss (>30% of original thickness), may have holes through the base metal	R4

(3)

Condition Indices for Civil Works

Condition Index Benefits

- quantification of condition
- discover hidden problems
- diagnosis of concerns
- benchmarking, trends - creation of a condition history
- a training tool, educational
- institutionalize knowledge
- supporting documentation for prioritization and justification of work
- tool for communication with management
- information source for contracting scopes of work
- quantification of condition
  - for components
  - for a system (report card)
- a simplified estimate of relative risk
- a simplified estimate of reliability
- a data source for detailed risk analysis

Condition Indices for Civil Works

Asset Management criteria

- Infrastructure performance (function)
  - Does the infrastructure provide the intended benefit?
    - Breakwaters & Jetties
    - Rec facility
    - Levee
    - Lock
    - Buildings

Condition Indices for Civil Works

Asset Management criteria

- Risk (reliability)
  - Computationally precise
  - Data intensive
  - Provides measure of costs and benefits
  - Different risks aren't easily comparable

Condition Indices for Civil Works

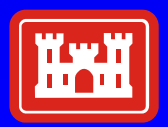
Asset Management criteria

- Economics
  - Pavements
    - Minimize M&R costs
  - Navigation
    - Reliability (minimum delays)
  - Flood Damage Reduction
    - Dam safety
  - Recreation
    - NED
  - Environment
    - Preservation

Condition Indices for Civil Works

Asset Management criteria

- Policies, Corps priorities, national priorities
  - Mandates
  - Constituent influence
  - Balanced program



Condition Indices for Civil Works

Asset Management M&R issues:

(budget prioritization issues)

- Reliability based
  - Safety and failure consequences
- Condition based
  - Deteriorated
- Quality of service (public facilities)
  - Modern, aesthetic, comfortable, dependable
- Performance
  - Not designed right or the need changes

Economics and Policy

Condition Indices for Civil Works

Condition Indices for Civil Works

Condition Indices for Civil Works

Red Rock Dam

Condition Indices for Civil Works

Condition Indices for Civil Works

Stewart Mountain

Condition Indices for Civil Works

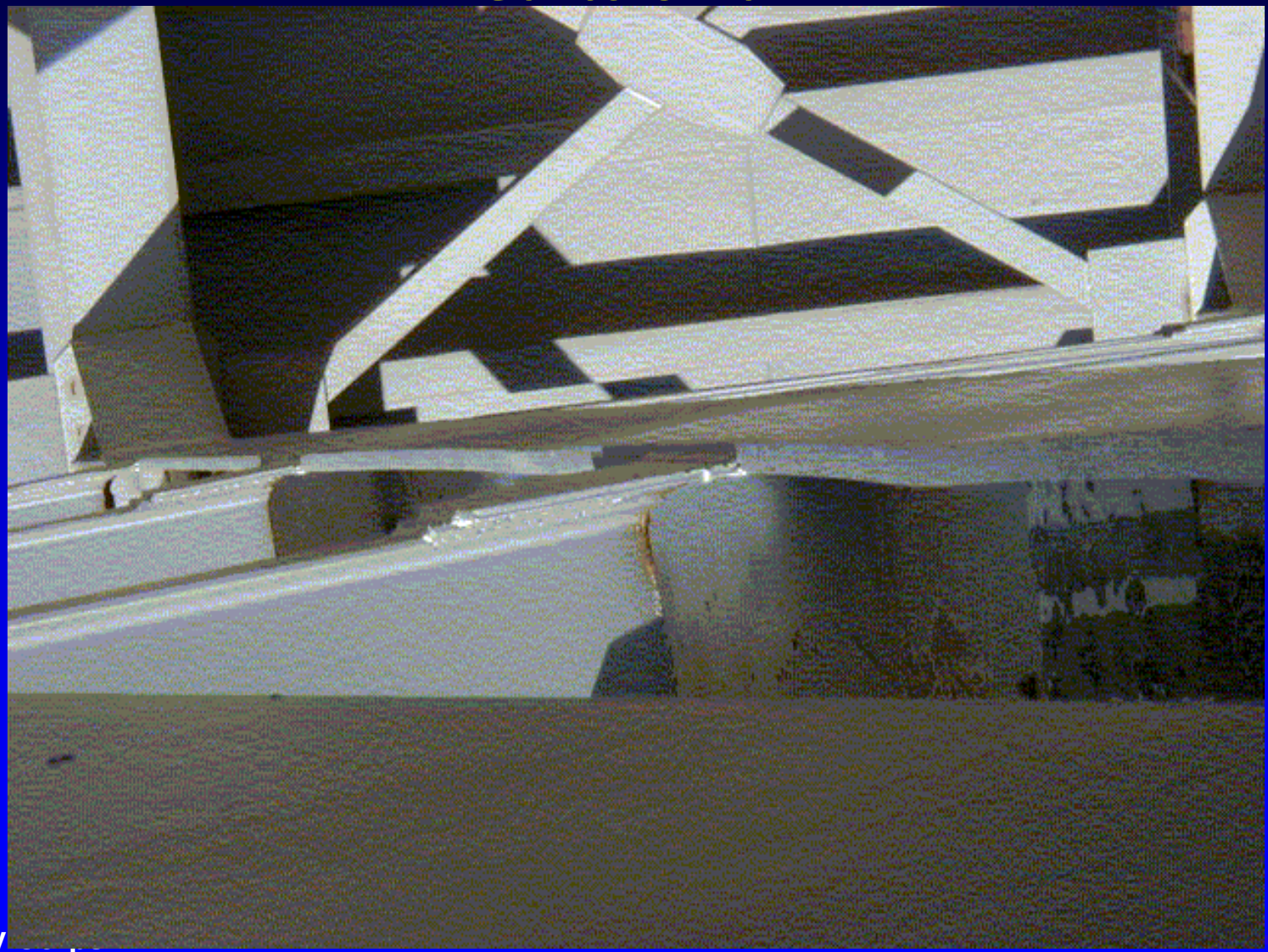
Stewart Mountain

Condition Indices for Civil Works

Condition Indices for Civil Works

Condition Indices for Civil Works

Carters Dam



Condition Indices for Civil Works

Condition Indices for Civil Works

- **This presentation:**
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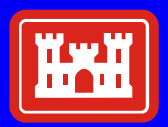
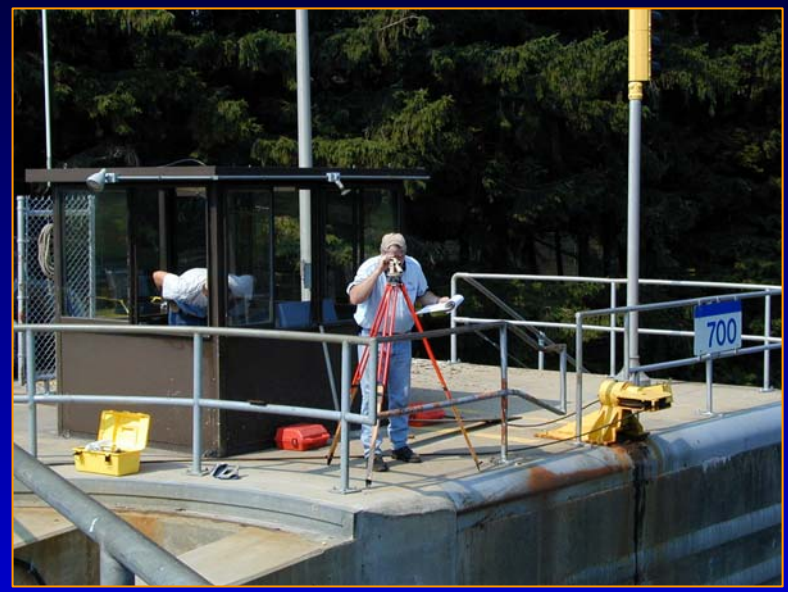


Condition Index (CI)

- Systematic Process
  - condition evaluation
- Inspection Procedures
  - based upon objective measurements
  - guidance if subjectivity unavoidable



- Rating Algorithms
  - create index(es)
  - 0 to 100
- Data is Valuable
  - raw numbers meaningful
  - track & quantify changes

Condition Indices for Civil Works

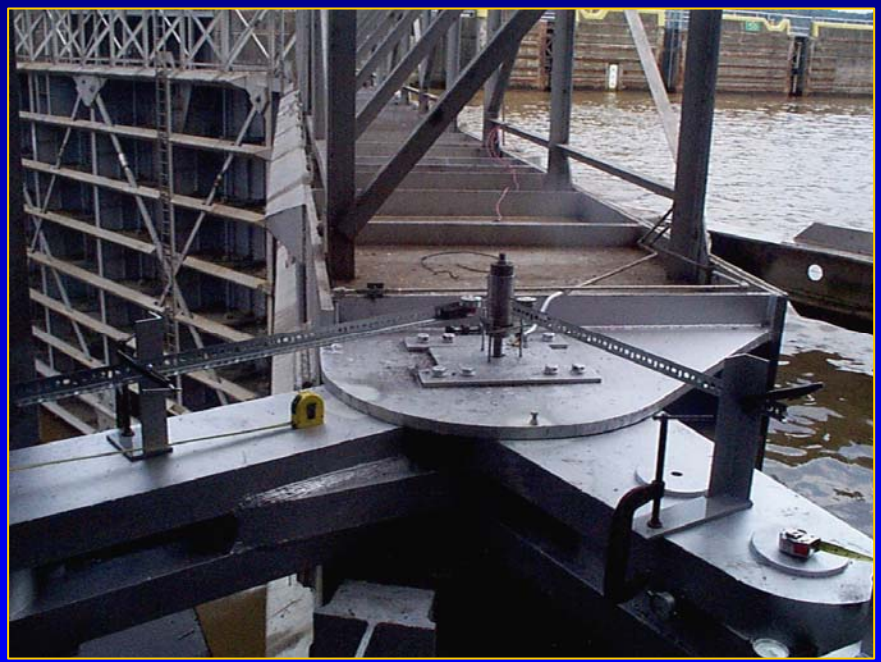
Condition Index Scale

Action Zone	Condition Index (CI)	Condition Description	Recommended Action
1	85 to 100	*Excellent:* No noticeable defects. Some aging or wear may be visible.	Immediate action is not required.
	70 to 84	*Good:* Only minor deterioration or defects are evident.	
2	55 to 69	*Fair:* Some deterioration or defects are evident, but function is not significantly affected.	Economic analysis of repair alternatives is recommended to determine appropriate action.
	40 to 54	*Marginal:* Moderate deterioration. Function is still adequate.	
3	25 to 39	*Poor:* Serious deterioration in at least some portions of the structure. Function is inadequate.	Detailed evaluation is required to determine the need for repair, rehabilitation, or reconstruction. Safety evaluation is recommended.
	10 to 24	*Very Poor:* Extensive deterioration. Barely functional.	
	0 to 09	*Failed:* No longer functions. General failure or complete failure of a major structural component.	

Condition Indices for Civil Works

CI - Inland Navigation

lock gates, lockwalls, valves, dikes and revetments



Condition Indices for Civil Works

CI Operating Equipment – All Business Areas

gears, couplings, racks, strut arms, rocker arms, chains, cable and hydraulic cylinders

Open Gears

Enclosed Gears & Oil

Condition Indices for Civil Works

CIs in Coastal Navigation
breakwaters and jetties

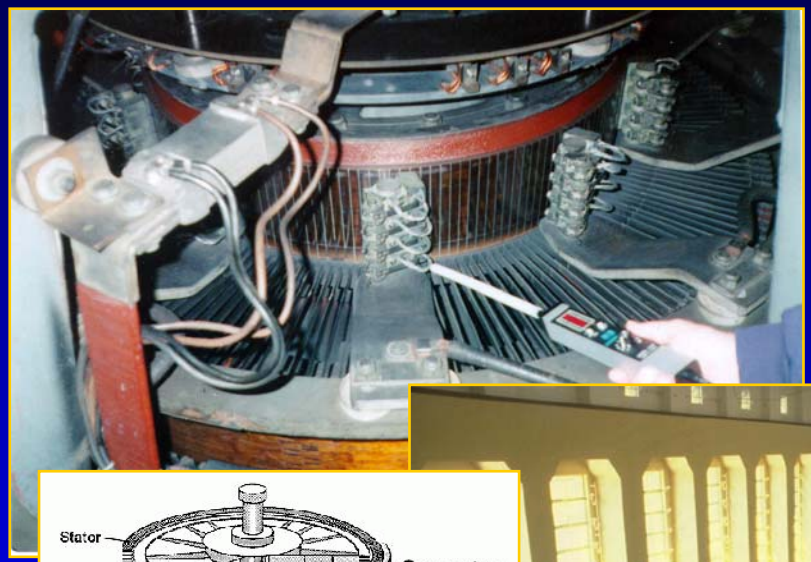
Condition Indices for Civil Works

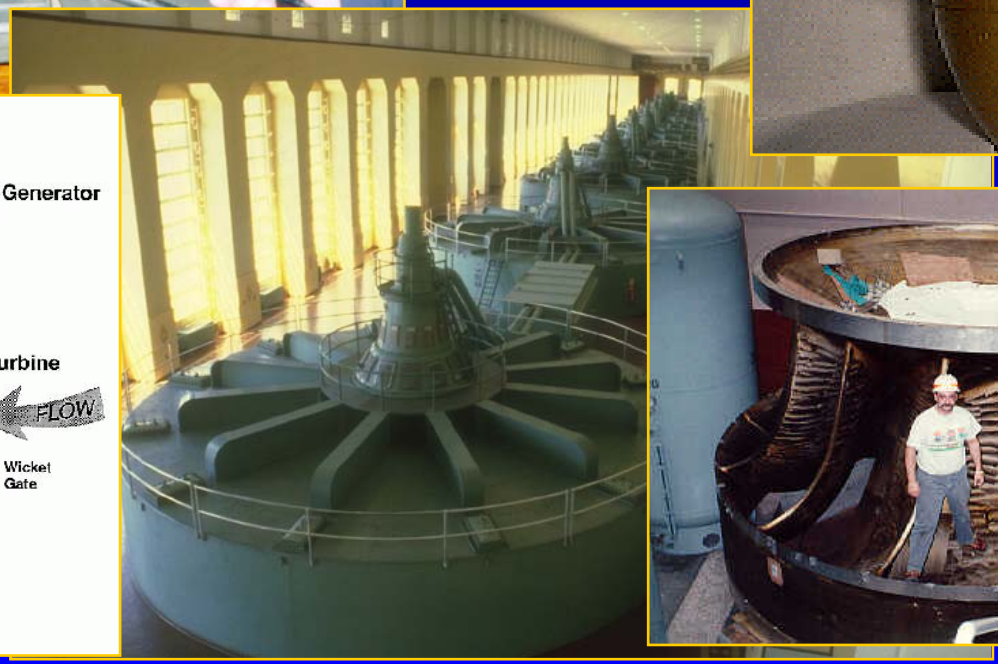
CIs in Flood Control

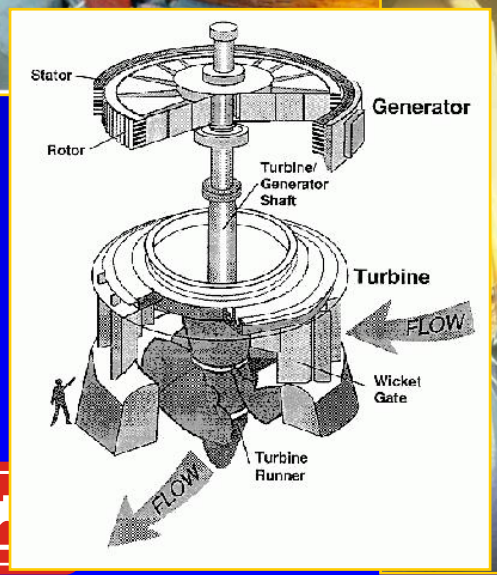
concrete dams, embankment dams, gates

Condition Indices for Civil Works

CIs in Hydropower







Condition Indices for Civil Works

Condition Index Benefits

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- quantification of condition
  - for components
  - for a system (report card)
- a simplified estimate of relative risk
- a simplified estimate of reliability
- a data source for detailed risk analysis

Condition Indices for Civil Works

- HQ issues
  - HQ mandated use but never looked at CIs rating
  - No policy for how to implement CIs
    - No uniformity in CI usage
  - Funding streams
    - O&M vs CG repairs
    - Automated Budgeting System - Baseline, Deferrable, Non-deferrable, Beyond ability

Condition Indices for Civil Works

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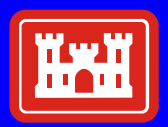
Condition Indices for Civil Works

- Perception & Problem:
  - CI's too expensive
  - Payback (benefit) takes some time to realize
- Objective:
  - encourage broader use of index style methodology and meet the specific need
- Approach
  - make CI procedures simpler, faster, cheaper
  - minimize impact on original technical integrity



Condition Indices for Civil Works

- Two simplification approaches
  - reduction by minutiae
    - step by step with stopwatch
    - simplify measurements
  - multi level / intensity inspections
    - purpose driven
    - first asks what is the information for
    - uses yes/no format to recommend inspection levels of varying complexity

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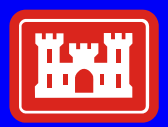
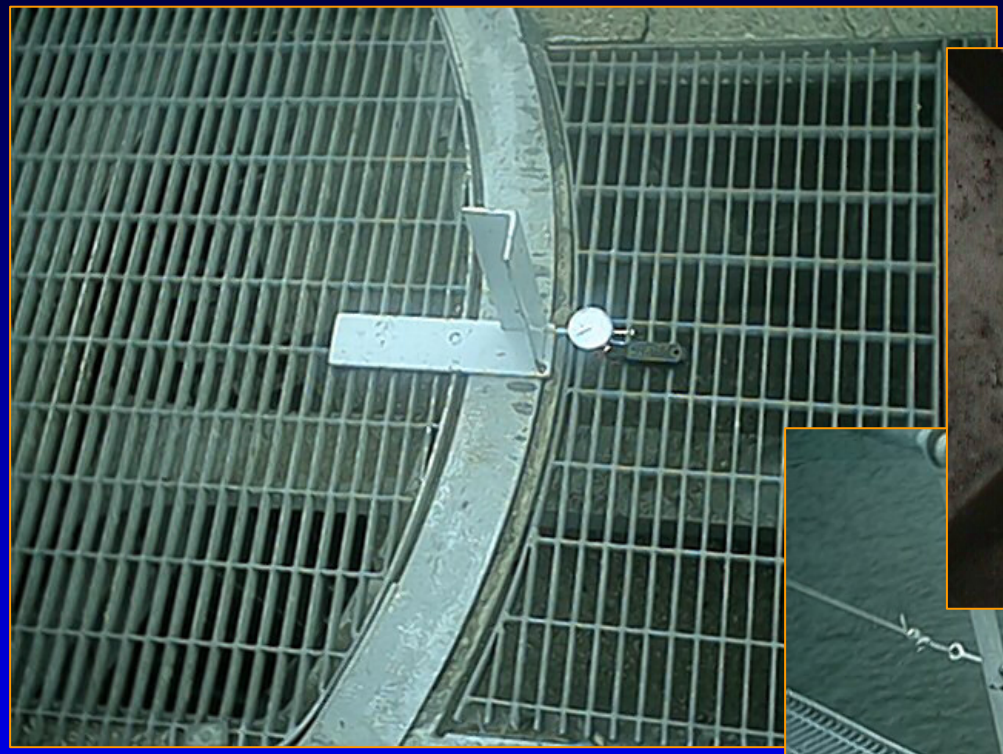
Miter Gate Measurements

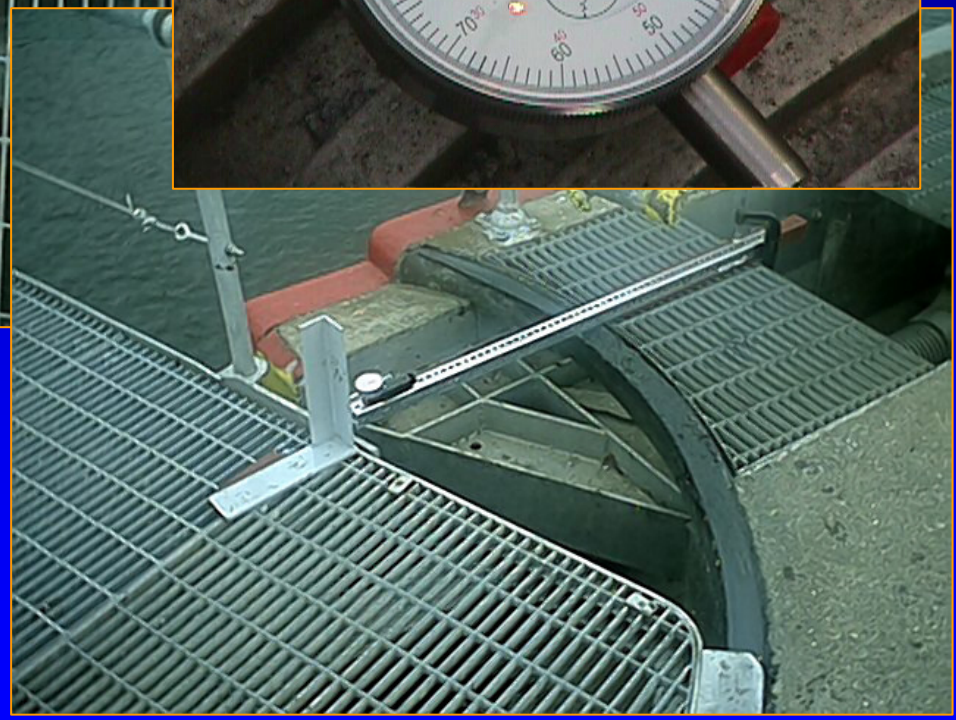
• Anchorage Movement	18% *(relative importance)*
• Elevation Changes	14%
• Miter Offset	08%
• Bearing Gaps	13%
• Downstream movement	11%
• Cracks	10%
• Leaks & Boils	05%
• Dents	02%
• Noise & Vibration	11%
• Corrosion	08%



We're Trying to Reduce This

To Something Like This

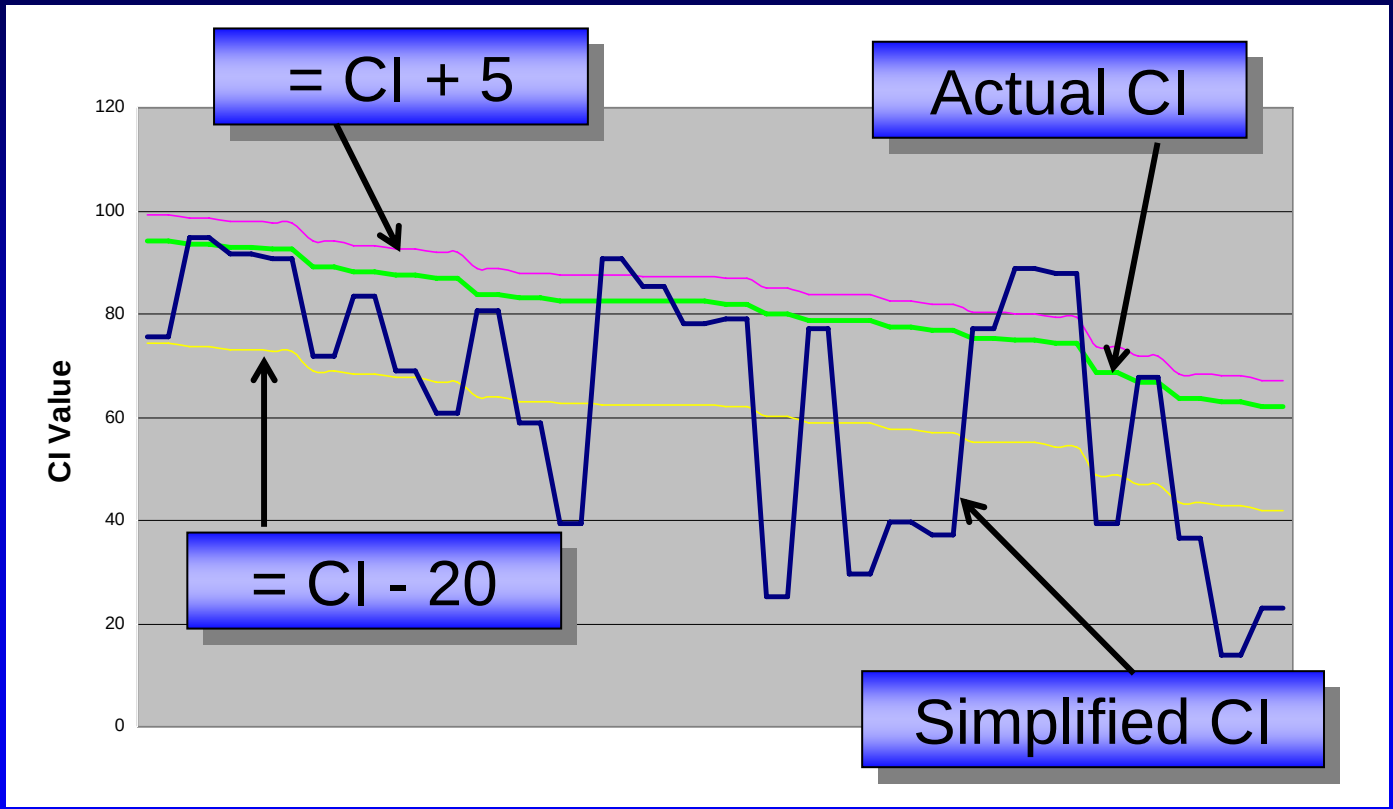




simplified measurement for anchorage assembly

Condition Indices for Civil Works

Actual CI vs. Simplified CI Using Real Data



104 vertically framed leaves (decreasing CI)

Condition Indices for Civil Works

- Miter Gate CI procedures
  - most “intensely objective” of all
  - nine other miter gate measurements
    - gages on anchor bars easy
    - use of binoculars in lieu of boat inspection
    - multi level / intensity check sheet will tell you if more measurements should be taken
- In many cases will be able to reduce the entire miter gate inspection time by 50% to 75%

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Condition Indices for Civil Works

Simplified CI - multi-level inspection approaches

- Level 1: desktop, based on existing data
- Level 2: walk around, yes/no type questions
  - function, needs or frequency based
  - criteria for moving to Level 3 or 4 inspection
- Level 3: specific component(s)
  - simplified procedure
  - by the orange book (as designed)
- Level 4: full scale engineered evaluation

Condition Indices for Civil Works

Lifting device structure (steel)

Function	Provide structural support for the hoisting device (and carrying tracks for mobile hoisting device)								
Excellent	Comprehensive structural inspection has been performed. All critical structural members fully accessible for inspection. No visible cracks, no visible member deformation, no corrosion, no missing bolts or members, no visible misalignment.								
Failed	Visible deformations, missing parts, or cracks of a load-carrying member. Corrosion resulting in the loss of more than 20% of the cross-section of critical structural member. Missing bolts or cracked welds on a facture critical member or connection (a non-redundant tensile member or connection whose loss would result in the collapse of the structure).								
Indicator	0 -- 9	10 -- 24	25 -- 39	40 -- 54	55 -- 69	70 -- 84	85 -- 100	Score	Comments
Displacement and deterioration									
No misalignment in a dedicated hoisting mechanism							X	100	
Displacement and deterioration of the structure causing visible or measurable misalignment in a hoisting mechanism with no effect on lifting						X			
Displacement and deterioration of the structure causing visible or measurable misalignment in a hoisting mechanism with excessive noise and vibration				X	X				
Displacement and deterioration of the structure causing visible or measurable misalignment in a hoisting mechanism with motor overload		X	X						
Displacement and deterioration of the structure causing visible or measurable misalignment in a hoisting mechanism that cannot be lifted	X								
Anchor bolts									
No corrosion							X		
Corrosion on nuts and bolts				X	X	X		80	some rust
Cracks in the concrete around the bolt and or missing concrete around the bolt		X	X						
At least one missing bolt or nut	X								
Cracks									

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Condition Indices for Civil Works

Relative Risk CIs

- Provide framework for engineering assessment
  - Identify and quantify issues
  - No black box calculation
    - Calculations based on the engineers' priorities and ratings
- Assessment of performance (coastal)
- Risk based assessment (spillway and embankment)
- Not an inspection procedure (spillway and embankment)
- Provides measure of priority (spillway and embankment)
- Example CIs
  - Coastal structures
  - Embankment dams (geotechnical)
  - Spillways (gates – struct, mech, elect, ops)

Condition Indices for Civil Works

Relative Risk CIs

Embankment dams

- Developers: Corps, Hydro Quebec
- Users: Hydro Quebec, Manitoba Hydro, EDF

Spillways

- Developers: Corps, Hydro Quebec, BurRec, Manitoba Hydro, Ontario Hydro
- Users: Hydro Quebec, Manitoba Hydro, EDF

Condition Indices for Civil Works

Relative Risk CIs

- CI methods for risk analysis
  - Not a fatigue or load capacity measure
  - Does not replace reliability or risk analysis
  - Provides a simpler complement to other methods
    - Think multi-level
    - No data issues
  - Used by Hydro Quebec for all dam safety prioritization

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Condition Indices for Civil Works

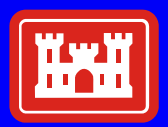
Conclusions

- Inspection and assessment of infrastructure is a valuable component of infrastructure management
- Maintenance & Repair for a large, complex and varied infrastructure requires many technical and decision support tools
- ERDC has developed processes and methodologies to support many of these decisions within the Civil Works community but more remains to be done.

Condition Indices for Civil Works

My objectives (workshop)

- ✓ Appreciate what information is needed for Asset Management (macro level understanding)
- ✓ Appreciate *condition assessment* as an Asset Management tool
- ✓ See condition Indexes as a family of capabilities



Condition Indices for Civil Works

http://www.cecer.army.mil/fl/remr/remr.html